Name _____ Class _____ Date _____

9.1 Cellular Respiration: An Overview

Lesson Objectives

- Explain where organisms get the energy they need for life processes.
- Define cellular respiration.
- Compare photosynthesis and cellular respiration.

Lesson Summary

Chemical Energy and Food Chemical energy is stored in food molecules.

- Energy is released when chemical bonds in food molecules are broken.
- Energy is measured in a unit called a **calorie**, the amount of energy needed to raise the temperature of 1 gram of water 1 degree Celsius.
- Fats store more energy per gram than do carbohydrates and proteins.

Overview of Cellular Respiration **Cellular respiration** is the process that releases energy from food in the presence of oxygen.

- Cellular respiration captures the energy from food in three main stages:
  - glycolysis
  - the Krebs cycle
  - the electron transport chain
- Glycolysis does not require oxygen. The Krebs cycle and electron transport chain both require oxygen.
  - **Aerobic** pathways are processes that require oxygen.
  - **Anaerobic** pathways are processes that occur without oxygen.

Comparing Photosynthesis and Cellular Respiration The energy in photosynthesis and cellular respiration flows in opposite directions. Their equations are the reverse of each other.

- Photosynthesis removes carbon dioxide from the atmosphere, and cellular respiration puts it back.
- Photosynthesis releases oxygen into the atmosphere, and cellular respiration uses oxygen to release energy from food.

Chemical Energy and Food

For Questions 1–4, complete each statement by writing the correct word or words.

1. A calorie is a unit of _____.

2. The Calorie used on food labels is equal to _____calories.

3. A Calorie is also referred to as a _____.

4. Cells use the energy stored in chemical bonds of foods to produce compounds that directly power the cell's activities, such as _____.

Overview of Cellular Respiration

For Questions 5–10, complete each statement by writing the correct word or words.

5. The equation that summarizes cellular respiration, using chemical formulas, is _____.

6. If cellular respiration took place in just one step, most of the _____would be lost in the form of light and _____.

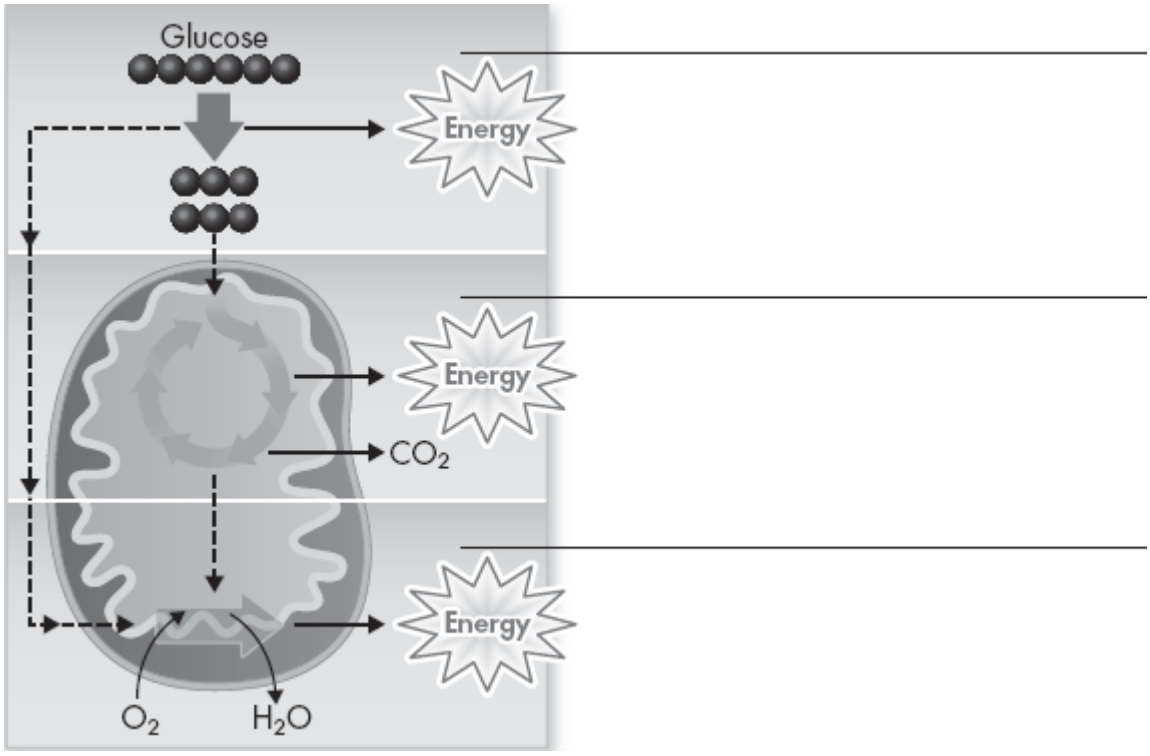
7. Cellular respiration begins with a pathway called _____, which takes place in the _____of the cell.

8. At the end of glycolysis, about _____ percent of the chemical energy is locked in the bonds of the _____ molecule.

9. Cellular respiration continues in the _____ of the cell with the _____ and electron transport chain.

10. The pathways of cellular respiration that require oxygen are said to be _____. Pathways that do not require oxygen are said to be _____.

11. **THINK VISUALLY** Complete the illustration by adding labels for the three main stages of cellular respiration.



Comparing Photosynthesis and Cellular Respiration

For Questions 12–15, write True if the statement is true. If the statement is false, change the underlined word or words to make the statement true.

_____ **12.** The energy flow in photosynthesis and cellular respiration occurs in the same direction.

_____ **13.** Photosynthesis deposits energy in Earth's "savings account" for living organisms.

_____ **14.** Cellular respiration removes carbon dioxide from the air.

_____ **15.** Photosynthesis takes place in nearly all life.

16. Complete the table comparing photosynthesis and cellular respiration.

A Comparison of Photosynthesis and Cellular Respiration

Aspect	Photosynthesis	Cellular Respiration
Function	energy capture	
Location of reactions	chloroplasts	
Reactants		
Products		

Apply the Big idea

17. How does an understanding of the process of cellular respiration support the theory that the cell is the basic functional unit of life?

9.2 The Process of Cellular Respiration

Lesson Objectives

- Describe what happens during glycolysis.
- Describe what happens during the Krebs cycle.
- Explain how high-energy electrons are used by the electron transport chain.
- Identify how much ATP cellular respiration generates.

Lesson Summary

Glycolysis The word **glycolysis** literally means "sugar-breaking." The end result is 2 molecules of a 3-carbon molecule called pyruvic acid.

- 2 ATP molecules are used at the start of glycolysis to get the process started.
- High-energy electrons are passed to the electron carrier **NAD^+**, forming two molecules of NADH.
- 4 ATP are synthesized during glycolysis for a net gain of 2 ATP.

The Krebs Cycle The second stage of cellular respiration is the **Krebs cycle**, which operates only when oxygen is available. The Krebs cycle is a series of energy-extracting reactions.

- Pyruvic acid produced by glycolysis enters mitochondria. In the innermost compartment of a mitochondrion, or the **matrix**, pyruvic acid molecules are broken down into carbon dioxide and acetyl-CoA molecules.
- Acetyl-CoA combines with a 4-carbon compound, producing a 6-carbon molecule—citric acid. Energy released by the breaking and rearranging of carbon bonds is captured in ATP, NADH, and $FADH_2$.
- The Krebs cycle produces four types of products:
  - high-energy electron carriers (NADH and $FADH_2$)
  - carbon dioxide
  - 2 ATP molecules (per glucose molecule)
  - the 4-carbon molecule needed to start the cycle again

Electron Transport and ATP Synthesis The electron transport chain uses the high-energy electrons from glycolysis and the Krebs cycle to convert ADP into ATP.

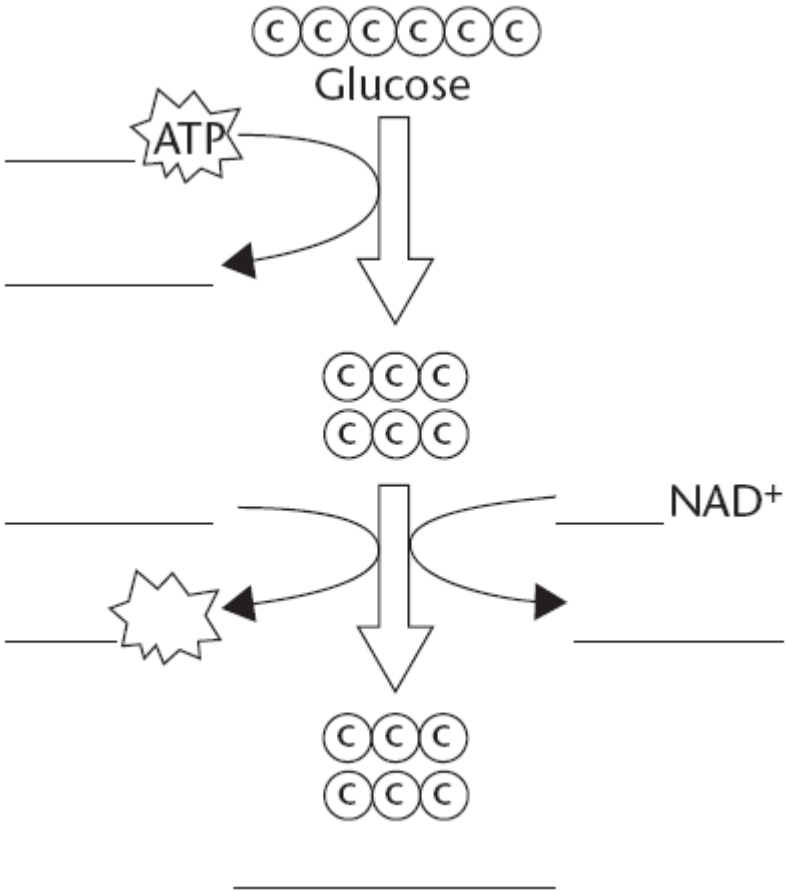
- The electron carriers produced during glycolysis and the Krebs cycle bring high-energy electrons to the electron transport chain. Oxygen is the final electron acceptor.
- The passing of electrons through the electron transport chain causes H^+ ions to build up in the intermembrane space, making it positively charged relative to the matrix.
- The charge difference across the membrane forces H^+ ions through channels in enzymes known as ATP synthases. As the ATP synthases spin, a phosphate group is added to ADP, generating ATP.

The Totals Together, glycolysis, the Krebs cycle, and the electron transport chain generate about 36 molecules of ATP per molecule of glucose.

Glycolysis

THINK VISUALLY

1. Complete the diagram by writing on the lines provided the names and numbers of molecules used and produced during glycolysis.



2. Why is it an investment for the cell to use two ATP at the beginning of glycolysis?

3. What are two advantages of glycolysis?

The Krebs Cycle

For Questions 4–7, write True if the statement is true. If the statement is false, change the underlined word or words to make the statement true.

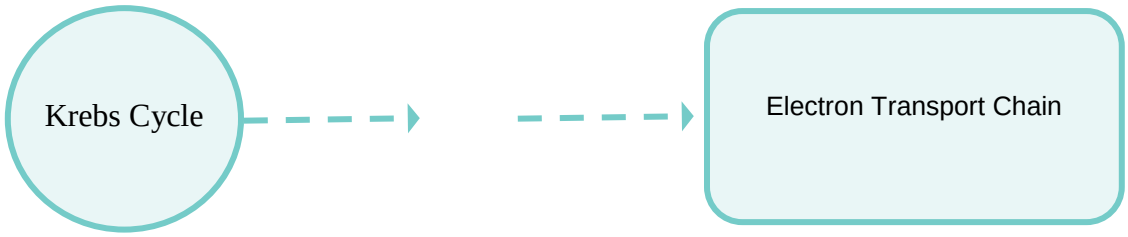
_____ **4.** The pyruvic acid produced in glycolysis enters the chloroplasts if oxygen is present in a cell.

_____ **5.** In the matrix, pyruvic acid is converted to lactic acid before the Krebs cycle begins.

_____ **6.** The compound that joins with a 4-carbon molecule in the Krebs cycle is called acetyl-CoA.

_____ **7.** Carbon dioxide is the only product of the Krebs cycle that is not re-used or used in other stages of cellular respiration.

8. Complete the flowchart to show which of the Krebs cycle's many products go on to the third stage of cellular respiration.



Electron Transport and ATP Synthesis

For Questions 9–14, complete each statement by writing the correct word or words.

9. In eukaryotes, the electron transport chain is composed of a series of electron carriers located in the_____of the mitochondrion.

10. In prokaryotes, the electron transport chain is in the _____.

11. _____ serves as the final electron acceptor of the electron transport chain.

12. _____ and _____ pass high-energy electrons to the electron transport chain.

13. The transfer of high-energy electrons down the electron transport chain causes ___ to be transported across the mitochondrial membrane.

14. ATP synthases produce the force needed to add one _____ to each ADP molecule by spinning when hydrogen ions flow through them.

Apply the Big idea

18. Where does the heat that warms your body come from? Explain your answer.

_____

_____

_____

_____

_____

9.3 Fermentation

Lesson Objectives

- Explain how organisms get energy in the absence of oxygen.
- Identify the pathways the body uses to release energy during exercise.

Lesson Summary

Fermentation **Fermentation** releases energy from food molecules by producing ATP without oxygen. Cells convert NADH to the electron carrier NAD^+. This allows glycolysis to produce a steady stream of ATP. There are two forms of fermentation. Both start with the reactants pyruvic acid and NADH.

- alcoholic fermentation produces ethyl alcohol and carbon dioxide
  - occurs in yeast and a few other microorganisms
  - produces alcoholic beverages and causes bread dough to rise
- lactic acid fermentation produces lactic acid
  - occurs in most organisms, including humans
  - used to produce beverages such as buttermilk and foods such as cheese, yogurt, and pickles

Energy and Exercise The body uses different pathways to release energy.

- For short, quick bursts of energy, the body uses ATP already in muscles as well as ATP made by lactic acid fermentation.
- For exercise longer than about 90 seconds, cellular respiration is the only way to continue generating a supply of ATP.

Fermentation

For Questions 1–6, write True if the statement is true. If the statement is false, change the underlined word or words to make the statement true.

_____ **1.** Glycolysis provides the pyruvic acid molecules used in fermentation.

_____ **2.** Fermentation allows glycolysis to continue by providing the NADPH needed to accept high-energy electrons.

_____ **3.** Fermentation is an aerobic process.

_____ **4.** Fermentation occurs in the mitochondria of cells.

_____ **5.** Alcoholic fermentation gives off carbon dioxide and is used in making bread.

_____ **6.** Most organisms perform fermentation using a chemical reaction that converts pyruvic acid to lactic acid.

7. Compare and contrast fermentation and cellular respiration by completing the compare/contrast table. Write your answers in the empty table cells.

Aspect	Fermentation	Cellular Respiration

Function		
Reactants		
Products		

8. Compare and contrast alcoholic fermentation and lactic acid fermentation by completing the compare/contrast table. Write your answers in the empty table cells.

Type of Fermentation	Summary Equation	Use in Industry
Alcoholic		
Lactic acid		

9. What causes humans to become lactic acid fermenters?

_____

_____

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